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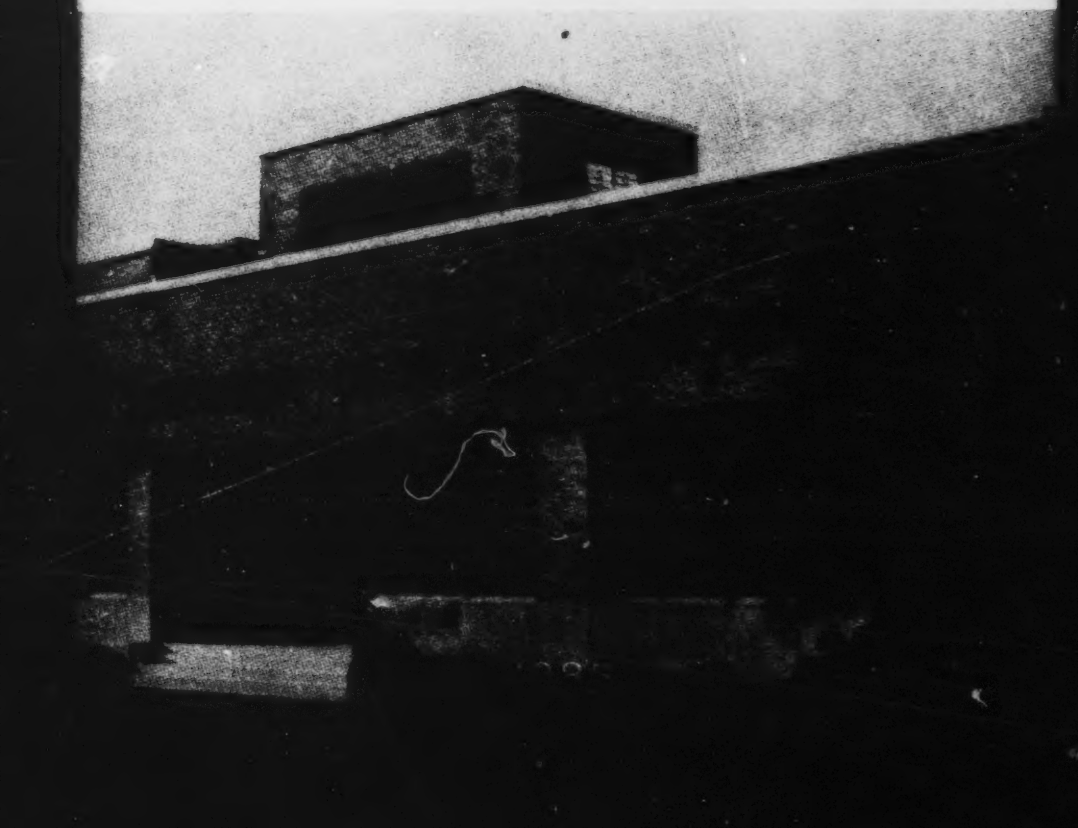
Canadian Forestry Service

Environnement Canada
Service canadien des forêts

1983-84 PROGRAM REVIEW

Forest Pest Management Institute



Our cover picture shows the Laboratory of Insect Pathology built by the federal government in 1949-50. Within these walls, and under the direction of Dr. J. McBain Cameron - from the laboratory's inception until his death in 1975 - much of the fundamental research leading to the development of modern-day bioinsecticides has been carried out. This research laboratory was later named the Insect Pathology Research Institute (IPRI) and when IPRI became part of the Forest Pest Management Institute in 1977, it became known as the Cameron Building in memory of its first director. This research landmark will soon disappear and will be replaced, by September, 1985, by a major new laboratory extension to the Great Lakes Forest Research Centre/Forest Pest Management Institute research complex. Though its physical presense will no longer be evident, the tradition of research excellence in pathology, established within its walls, will live on in the new research complex.

PROGRAM REVIEW 1983-84

FOREST PEST MANAGEMENT INSTITUTE
CANADIAN FORESTRY SERVICE
ENVIRONMENT CANADA

1984

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THE CANADIAN FORESTRY SERVICE

ENVIRONMENT CANADA

The Canadian Forestry Service (CFS) is the principal source of federal expertise in forestry. Its general objective is to promote the wise management and use of Canada's forest resource for the economic, social, and environmental benefit of Canadians.

The following are the main functions of the CFS:

1. Providing coordinated federal policies to promote forest industry development and better resource management;

2. Providing scientific and technical leadership through research and development;

3. Providing and analyzing national and international information and statistics as a basis for policy;

4. Aiding in developing and certifying codes and standards of product performance;

5. Protecting Canada's forests from foreign pests;

6. Supporting provincial forest renewal programs to ensure permanent viability of the forest resource;

7. Fostering the potential use of the forest resource for energy; and,

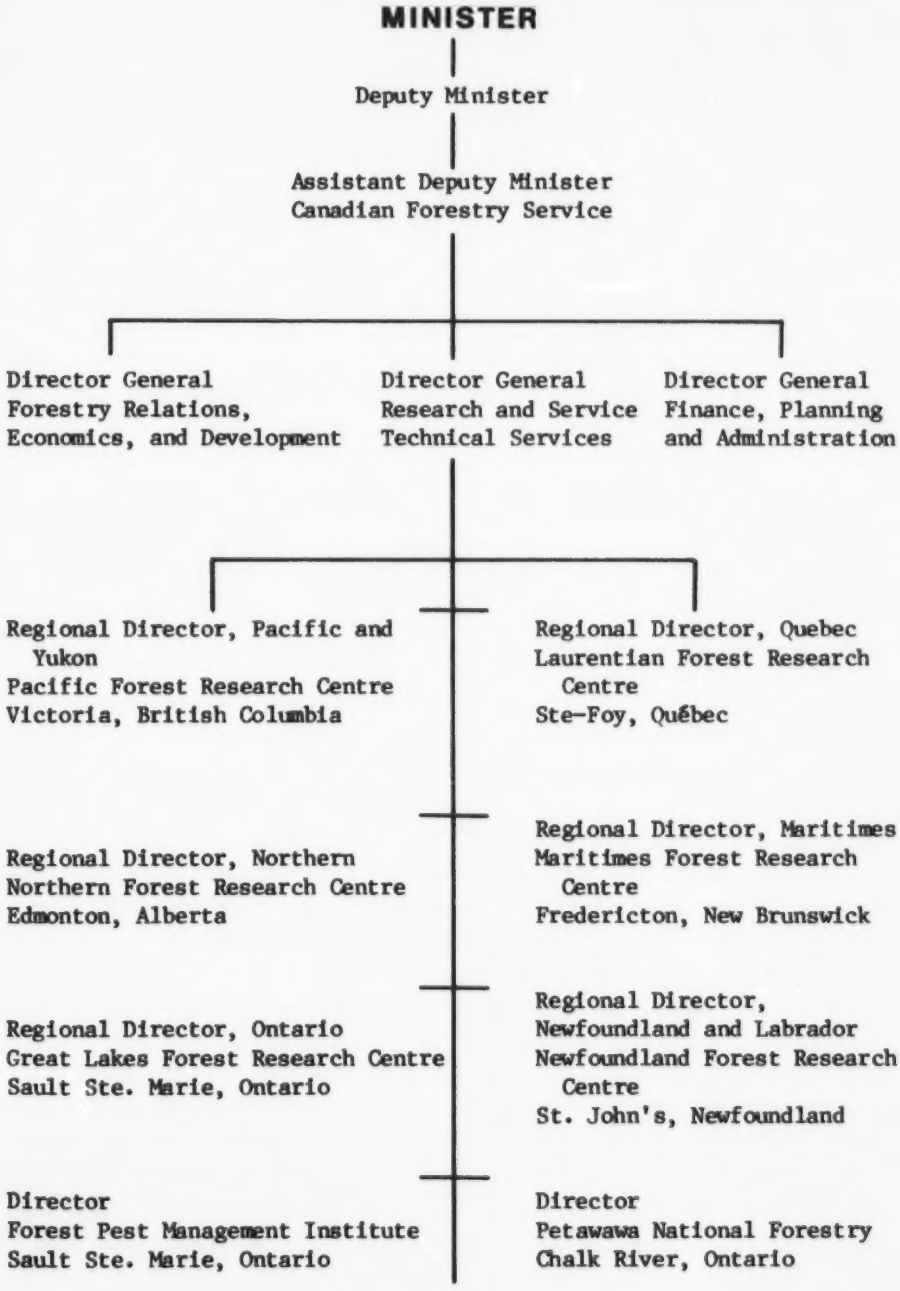
8. Contributing to the environmental objectives of the Department of the Environment.

A number of federal agencies are involved in forestry programs, and a Federal Forestry Sector Strategy Committee has been established to coordinate federal forestry activities. The CFS has been designated the lead agency.

In September, 1982, the Canadian Forestry Service assumed responsibility for regional economic development from a forestry standpoint. In this context the Service is required to negotiate federal-provincial forest renewal agreements of intensive forest management practices to meet the objective of the federal forest sector strategy. As a result, the CFS is also involved in the development of economic profiles and studies to identify regional and national needs, and development opportunities.

The Canadian Forestry Service is composed of a headquarters unit, six forest research centres, and two national institutes. The forest research centres are responsive to regional priorities and maintain close liaison with the respective provincial government forestry departments. They also participate in, and frequently lead, national programs. The national institutes provide the focus for programs of national scope. The headquarters unit comprises three directorates - Research and Technical Services, which plans, directs and coordinates the research and development programs and technical services of the CFS; Forestry Relations, Economics, and Development, which handles forestry relations with university, industry and other governments, economic analyses, as well as the coordination of the forestry development and employment stimulation programs; and Finance, Planning, and Administration, which manages the support services of the CFS in planning and program evaluation, finance, administration, and human resources management.

Environment Canada



SERVICE CANADIEN DES FORÊTS

ENVIRONNEMENT CANADA

Le Service canadien des forêts (SCF) réunit la majorité des spécialistes fédéraux en foresterie. Son objectif général est de promouvoir l'aménagement et l'utilisation judicieux des ressources forestières du Canada pour le plus grand bien économique, social et environnemental des Canadiens.

Voici les principales fonctions du SCF:

1. Fournir des politiques fédérales coordonnées afin de favoriser l'expansion de l'industrie forestière et l'amélioration de la gestion des ressources;

2. Fournir une orientation scientifique et technique par la recherche et le développement;

3. Fournir et analyser l'information et les statistiques nationales et internationales qui serviront de base aux politiques;

4. Aider à la mise au point et à la certification des codes et des normes en matière de performance des produits;

5. Protéger les forêts canadiennes en luttant contre les ravageurs étrangers;

6. Appuyer les programmes provinciaux de régénération forestière afin d'assurer la viabilité permanente des ressources forestières;

7. Parrainer l'utilisation éventuelle des ressources forestières pour la production d'énergie; et

8. Adhérer aux objectifs environnementaux du ministère de l'Environnement.

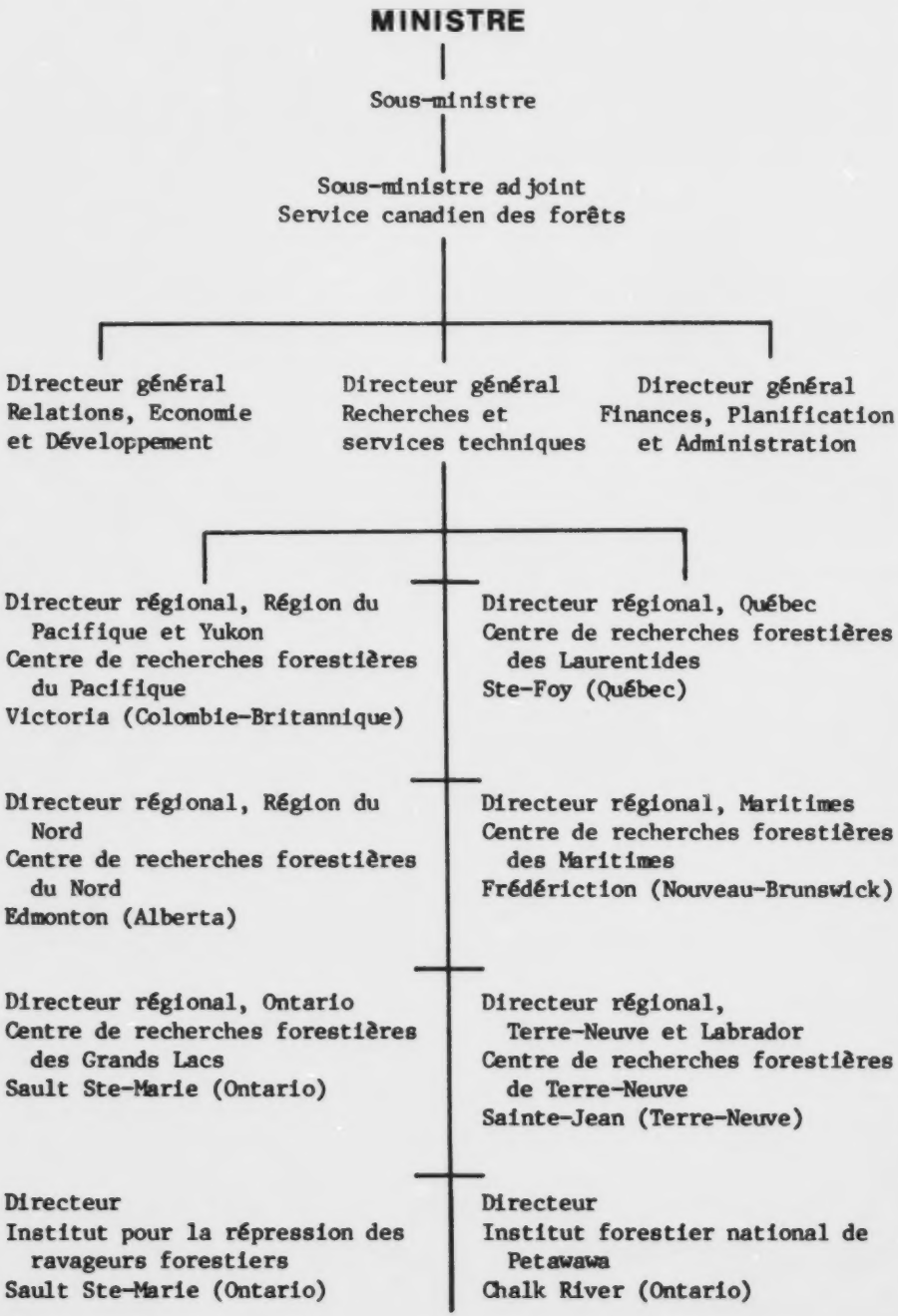
Depuis septembre 1982, le SCF assume la responsabilité du développement économique régional dans le domaine forestier. À ce titre, il doit conclure des ententes fédérales-provinciales, relatives à la régéneration forestière, sur des méthodes de gestion intensive des forêts afin d'atteindre les objectifs de la stratégie forestière du Canada. Le SCF doit conséquemment participer à la mise au point de profils et d'études économiques afin de cerner les besoins sur les

plan régional et national, de même qu'aux possibilités de développement.

Le SCF comprend une administration centrale, six centres de recherche forestière et deux instituts nationaux. Les centres de recherche forestière doivent répondre aux impératifs régionaux et entretenir une liaison étroite avec les ministères provinciaux des forêts. Ils participent également à des programmes nationaux dont ils assument fréquemment la direction. Les instituts nationaux sont les foyers des programmes d'envergure nationale.

L'Adminstration centrale comprend trois directions générales: Recherche et Services technqiues, dont le rôle consiste à planifier, diriger et coordonner les programmes de recherche et développement ainsi que les services techniques du SCF; Relations, Économie et Développement, qui s'occupe des relations forestières avec les universités, l'industrie et les autres gouvernements, d'analyses économiques ainsi que de la coordination des programmes de développement forestier et de création d'emplois; et Finances, Planification et Administraton, qui dirige les services de soutien du SCF dans la planification, l'évalution des programmes, les finances, l'administration et la gestion du personnel.

Ministère de L'Environnement



Director's Foreword

The Forest Pest Management Institute (FPMI) was formed in 1977 through amalgamation of the former Insect Pathology Research Institute, Sault Ste. Marie and the former Chemical Control Research Institute, Ottawa. Transfer of the latter to Sault Ste. Marie was completed by the fall of 1979. The total staff of 87 person years is accommodated in the former IPRI building and in space modified to meet FPMI requirements in the Great Lakes Forest Research Centre facility. A capital construction program currently underway will accommodate all Institute staff under one roof by the fall of 1985.

This amalgamation brought under one direction extensive expertise within the Canadian Forestry Service (CFS) in biological control agents, chemical pesticides, application technology and environmental concerns. It has provided a unique opportunity to develop a Research and Development (R & D) program that can provide forest managers with effective pest management strategies in a more comprehensive and coordinated manner than has been possible in the past.

The Forest Pest Management Institute shares the overall objective of the Canadian Forestry Service: "To promote the wise management and use of Canada's forest resources for the economic, social and environmental benefit of Canadians". The Institute's R & D program is devoted exclusively to the development of efficacious, environmentally acceptable pest management strategies that will assist forest managers to achieve forest management objectives.

As a National Institute, FPMI's research interests and mandate transcend regional boundaries. It brings together special expertise, research equipment and facilities that would be difficult to duplicate in regional research centres within the Canadian Forestry Service. Because of this, the Institute's program attempts to support and add depth to pest management programs undertaken by CFS regional forest research centres and is therefore attuned to pest management problems facing provincial forest managers. Obviously, a cooperative approach to the solution of mutual problems is advantageous and, whenever possible, is practiced by the Institute and regional elements of the CFS and provincial forest authorities.

Research at FPMI is carried out within two major, national programs:

Improved Forest Management. If Canada's share of the foreign market in wood and wood products is to be maintained or increased in the years to come, forestry in the 1980's must be committed to a massive

program of intensive forest management, including the return to productivity of a large and growing backlog of inadequately regenerated cutover. This commitment requires very large investments in regeneration and stand tending both to increase forest production and to enhance the social and aesthetic values of our forest resources.

It makes little sense, however, to invest heavily in these areas unless we are prepared to carry out effective pest management strategies against important forest insects and competing vegetation in order to limit losses to these agents to levels that will allow forest managers to capitalize on their investments and achieve desired forest management goals. The Institute's R & D program is comprised of a number of segments addressing the complex field of forest pest management. Within the Improved Forest Management portion of the national program, FPMI's research in Microbial Control Agents is aimed at developing naturally occurring insect pathogens (bacteria, viruses, fungi and protozoa) for forestry use. Our research in Biological Interactions includes investigations of insect tissue culture, cellular interactions, immunochemistry and biological systems analysis. Research in Physiological and Genetic Mechanisms investigates the utility of insect pheromones, growth regulators and genetic mechanisms in the control of important forest insect pests. Our program element in Pesticide Toxicology and Efficacy includes the toxicology and screening of chemical insecticides, field efficacy testing of promising candidate insecticides, the biology and control of plantation pests and the development and use of herbicides for site preparation and conifer release.

Environmental and Amenity Forestry. The intelligent use of pest control products demands that their use result in a minimal risk to the environment or to public health. While public health lies outside the mandate of FPMI and is best monitored by appropriate federal and provincial health agencies, the Institute is heavily involved in research on Environmental Impact and Chemical Accountability of pesticides. Such research is required to determine the effects of insecticides and herbicides on nontarget organisms in the forest environment and their persistence, dynamic cycling and ultimate fate following introduction into the forest ecosystem.

These R & D thrusts in Improved Forest Management and Environmental and Amenity Forestry are supported by an active Complementary Services program, which provides continuous supplies of a wide variety of insects, pathogens, plants, and animals for our researchers and their principal collaborators.

Data generated within the total Institute R & D program are essential for the development of new and improved pest control products for forestry use and for the development of strategies for their operational use which will optimize effectiveness and minimize adverse environmental impact. In addition, Institute research provides much of the data upon which the registration status of pest control products for forestry use is determined, and upon which effective yet environmentally benign use patterns are developed and promulgated under terms of the Pest Control Products Act.

G.W. Green
Director
1 April 1984

Improved Forest Management

Microbial Control Agents

A wide variety of naturally occurring insect pathogens, including bacteria, viruses, fungi, and protozoa, can have adverse effects on the survival and reproduction of forest insect pests. To increase the number of options available to the forest manager for control of economically important insect pests, biological control research at the Institute is aimed at identifying those insect pathogens that have control potential and identifying the conditions under which they can be used to prevent insect outbreaks, or to suppress them once they have occurred. When these conditions have been identified, strategies can be developed for the use of these pathogens, either by themselves or in concert with other control methods such as chemicals.

Institute research into biological control presently concentrates on three main areas; the identification of insect-specific pathogens for control use, the elucidation of the conditions under which these organisms exert their effect on naturally occurring populations, and the development of use patterns and strategies for their effective use. These projects investigate naturally occurring host-pathogen interactions, develop data necessary to support petitions for registration of certain viruses, and improve application strategies for registered agents. Research into a particular organism can overlap these categories in terms of understanding its natural occurrence and effectiveness and developing it for use.

FP-10 BACTERIAL PATHOGENS

PROJECT STAFF:

P.G. Fast (Project Leader), Study Leader (Vacant), R. Milne

OBJECTIVES: *To enhance the effectiveness of* Bacillus thuringiensis *and related bacterial pathogens for use in the control of forest insects in Canada.*

ACHIEVEMENTS: Previous work in this project has shown that the toxicity of *Bacillus thuringiensis (B.t.)* resides in the parasporal crystal produced when the bacterium sporulates. The last three instars of spruce budworm have been found to be susceptible to *B.t.* in laboratory and field situations. The effect of *B.t.* on spruce budworm larvae mortality has been found to be dependent on exposure time as well as on dose. A technique was developed to assess the efficacy of spray applications by comparing defoliation predicted on the basis of prespray larval counts with actual defoliation in sprayed plots at the end of larval growth.

In the summer of 1983, FPMI, MFRC (Maritimes Forest Research Centre), Forest Protection Limited, and the New Brunswick Research and Productivity Council participated in a cooperative study to validate the effect of foliar deposit of *B.t.* on efficacy in the field. Field efficacy was determined on a variety of parameters including defoliation and mortality.

The secondary structure of the protein was characterized from the available amino acid sequence of a portion of the crystal protein chain. The secondary structure is much more conserved in homologous proteins than is sequence. Because evidence indicates that this sequence is part of the toxic fragment, comparative studies will help identify the active site. It was also determined that in 1/3 of the crystal protein chain there are no repeating sequences.

PROJECTIONS: During 1984-85 work will concentrate on isolation of Manduca toxin and characterization of its action, the validation of inferred sequence of active toxin, and characterization of *B.t.* in foliar deposits on efficacy in lab and field.

FP-11 FUNGAL PATHOGENS

PROJECT STAFF:

D. Tyrrell (Project Leader), D. Perry (Study Leader), K. Humphries, M. Welton

OBJECTIVES: *To develop methods and procedures for the use of entomogenous fungi in the management of forest insects in Canada.*

ACHIEVEMENTS: Substantial contributions have been made by this project, since the 1950's to an understanding of the biology of entomogenous fungi. Significant progress has been made toward the development of these fungi as control agents. Resting spore germination has been achieved for five species of entomophthoraceous fungi and many of the factors affecting germination have been determined.

In 1983-84, conidial germination of *E. aulicae* was studied in relation to temperature, nutrients, and other compounds. It was found that the time of death of insects infected with *E. aulicae* showed a diurnal periodicity when the insects were subjected to a photoperiod, but not if they were exposed to continuous light. Field studies of fungus-spruce budworm interactions were continued in Lake Superior Provincial Park and expanded to include an emergent population near Black Sturgeon Lake. In collaboration with other scientists in FPMI and GLFRC (Great Lakes Forest Research Centre), data on spruce budworm population size and development, as well as the incidence of fungi, microsporidia and parasites were collected for each population. Fungi recorded included *E. radicans, E. egressa, B. bassiana, Paecilomyces,* and *Hirsutella* spp. A methodology for bioassay experiments in the greenhouse was developed for use with Entomophthorales fungi. The following models were adapted or constructed to aid in the design of experiments and to be used in the derivation of strategies for the operational use of fungi in forest pest management: i) A process model for temperature dependent development of *C. fumiferana.* ii) A process model of the life cycle of *Erynia radicans* based on developmental rates for each stage at different temperatures.

PROJECTIONS: Physiological studies will concentrate on determining the conditions necessary for germination, growth and sporulation of several species with potential for control use. Laboratory and field studies aimed at determining both the persistence of fungi in the environment and host-pathogen interactions will continue to determine conditions under which these fungi can be used effectively.

FP-12 PROTOZOAN PATHOGENS

PROJECT STAFF:

G.G. Wilson (Project Leader), E. Young

OBJECTIVES: *To investigate the host-parasite relationships of microsporidia and determine their potential for control of forest insect pests.*

ACHIEVEMENTS: This project has made significant progress over the past 15 years in elucidating the occurrence and effect of microsporidia in forest insect populations. These parasites were found to have a strong debilitating effect on their hosts. Microsporidia have been isolated and identified for a number of forest insect pests, including the spruce budworm, forest tent caterpillar, larch sawfly, and pine false webworm.

During 1983-84, tests were conducted to determine the susceptibility of third- and fifth-instar larvae of the forest tent caterpillar to *Nosema disstriae, Pleistophora schubergi* and *Vairimorpha necatrix.* Dosage-mortality responses of the spruce budworm to *N. fumiferanae* and *P. schubergi* were determined. Mean days to death decreased as dosage increased. Preliminary tests on the spruce budworm suggest that there may be a relationship between the intensity of *N. fumiferanae* spores in the adults and their offspring.

PROJECTIONS: The effects on mating behaviour of *N. fumiferanae* and *P. schubergi* infection in males will be examined. The study of the effects of intensity of *N. fumiferanae* in female adults and the effects this has on their offspring will be continued. Microsporidia intensity and infection levels in two field populations of the spruce budworm will be determined as part of a major study of the field ecology-population dynamics of this insect.

FP-13 VIRAL PATHOGENS

PROJECT STAFF:

J.C. Cunningham (Project Leader), B. Arif (Study Leader), W.J. Kaupp (Study Leader), M. Legris, K. Brown, R. Burke, B. Cunningham.

OBJECTIVES: *To develop viruses for effective and environmentally acceptable use in the population regulation of important forest insect pests.*

ACHIEVEMENTS: For about 35 years, this project has been devoted to the isolation, biochemical and biophysical characterization and evaluation of control potential of a variety of viruses affecting such important forest insect pests as spruce budworm, western spruce budworm, Douglas-fir tussock moth, gypsy moth, European spruce sawfly, European pine sawfly, and redheaded pine sawfly. Efficacy of these viruses has been tested in the laboratory, in small-scale ground applications and in aerial applications. Such parameters as dosage, timing of application, and formulation have been studied. Epizootiological investigations have also been made.

In 1983, temporary registrations were granted to Lecontvirus, for control of redheaded pine sawfly, and to Virtuss, for control of Douglas-fir tussock moth. In collaboration with staff of the Pacific Forest Research Centre (PFRC), follow-up studies were conducted in plots sprayed with nuclear polyhedrosis virus (NPV) and granulosis virus (GV) in 1982 to control western spruce budworm. Follow-up studies on plots sprayed with Virtuss in 1982 and results from a small ground spray trial in 1982 indicated that this virus may spread from treated to untreated areas. Gypsy moth NPV was monitored both in areas sprayed in 1982 and in untreated areas.

Considerable progress has been made in constructing a physical map of spruce budworm NPV DNA and this is the first step in genetic manipulation of the virus. Genetic studies have shown that alfalfa looper NPV is very closely related to spruce budworm NPV and that these two viruses probably evolved from a common ancestor. Restriction endonuclease enzyme analysis of TM BioControl-1 (American product) and Virtuss (Canadian product) showed that they contain identical viruses.

PROJECTIONS: An attempt will be made to upgrade the Lecontvirus and Virtuss temporary registrations to the status of full registrations by providing additional data requested by regulatory authorities. A registration petition for European pine sawfly NPV will be assembled using mostly American data. Monitoring of plots sprayed with spruce budworm NPV and GV in 1982 and gypsy moth NPV in 1982 will continue. The significance of droplet size of foliar sprays of viruses will be investigated. Epizootiological studies of spruce budworm NPV will continue and similar studies of gypsy moth NPV will be initiated. Genetic studies of spruce budworm NPV DNA will continue and certain regions of the DNA will be mapped in a more detailed manner as a prelude to ascribing various functions to parts of the genome. Also, repeated sequences in the genome will be investigated to determine if host DNA material is inserted into the viral DNA and, if this occurs, whether these insertions affect pathogenicity of the virus.

BIOLOGICAL INTERACTIONS

In a research program as broad as that of the Institute, there is an essential requirement for research into the biological effects of a variety of insect pest control methods, and for systems to study modes of action and identification. To conduct such research, and to develop information required for successful conduct of other Institute projects, four areas of investigation are carried out. These are: Tissue Culture, for the study of insect pathogens *in vitro;* Cell Biology, for the identification of normal cellular development and its alteration by control agents; Immunochemistry, for identification and characterization of pathogens and their constituents; and Biological Systems Analysis, for modelling and analysis of the underlying biological systems, assistance in experimental design, and methodology for interpretation and integration of results. In addition to significant individual contributions, these projects have strong ties across the Institute's research program.

FP-20 INSECT PATHOGENS *IN VITRO*

PROJECT STAFF:

S.S. Sohi (Project Leader), G. Caputo, B. Cook

OBJECTIVES: *To develop and apply insect tissue culture methodology for the* in vitro *investigation of insect pathogens with a view to enhancing their effectiveness in the management of forest insect pests.*

ACHIEVEMENTS: Over 35 continuous cell lines have been established from tissues of spruce budworm, forest tent caterpillar, whitemarked tussock moth, redheaded pine sawfly, and tobacco hornworm since 1963. Nuclear polyhedrosis viruses (NPV) of the original hosts have been propagated *in vitro* with these cell lines. Microsporidia have also been propagated to a more limited extent. Multiplication and morphogenesis of viruses and microsporidia in tissue culture have proved similar to those of pathogens grown *in vivo* and they remained infectious to the original hosts. A cell-based bioassay was developed for the *Bacillus thuringiensis (B.t.)* toxin using spruce budworm cell lines. Methods have been developed for large-scale propagation of cells and for long-term deep-freeze storage and recovery of insect cell lines. Several cell lines have been characterized by chromosome number and serological relationships. The NPV of both the whitemarked and Douglas-fir tussock moths grew very well in cell lines derived from the whitemarked tussock moth. The NPV of the spruce budworm grew very well in the homologous ovarian cell cultures.

In 1983-84, an *in vitro* bioassay was developed for the NPVs of the whitemarked and Douglas-fir tussock moths. An attached strain of whitemarked tussock moth cells was developed that will be very useful for NPV investigations. Of the 10 primary cultures of the spruce budworm pupal ovaries, three were developed into continuous cell lines. All three of these lines replicated an homologous NPV and an NPV of the alfalfa looper. Eleven of the 60 primary cultures of the western spruce budworm were subcultured several times. Twenty-eight cell lines were characterized by the isozyme analysis.

PROJECTIONS: Work on the attached strain of the white-marked tussock moth cells will be completed. Studies will be initiated on the kinetics of the spruce budworm NPV *in vitro*, and *in vitro* bioassays will be developed for this virus. Work will continue on developing cell lines of the western spruce budworm.

FP-21 CELLULAR INTERACTIONS

PROJECT STAFF:

J. Percy (Project Leader), J.A. MacDonald, D. Nicholson

OBJECTIVES: *To determine the ultrastructural characteristics of insect cells and tissues involved in production of biologically active agents as well as the modification of cells and cuticle resulting from the penetration and internal distribution of insect pest control agents in order to enhance the effectiveness of these agents.*

ACHIEVEMENTS: The production and transport of pheromones have been determined at the cellular and subcellular levels in several insect species. Such studies also identified more general mechanisms of transport of biologically active materials through cells and insect cuticle. Cooperative research with other projects has resulted in determination of the development and structure of a microsporidian infecting the larch sawfly, confirmation of the replication of the Douglas-fir tussock moth nuclear polyhedrosis virus (NPV) in an established cell line, and development of techniques for the study of virus replication in other cell lines. Other viruses from field-collected insects have been identified. Studies have been completed on the ultrastructure of the pheromone gland of the forest tent caterpillar, the mode of action of *B.t.* on gut cells, the presence and replication of tussock moth virus in cell lines, and on the ultrastructure of wax gland cells in larvae of *Eriocampa ovata* and the chemical analysis of the secretion.

During 1983-84, information on the ultrastructure of the female sex pheromone glands of several Lepidopteran families was integrated. Preliminary work was done to determine the

effect of accumulated wax in the balsam woolly aphid on penetration of insect control agents. Oenocytes of *Trichoplusia ni* are being used to see if they can produce hydrocarbons, an important constituent of insect cuticle. Continuing studies of 6th-instar spruce budworm larvae included examinations of material prepared to determine the effect of ingested IGR on cuticle development and to illustrate the distribution and progression of NPV and GV infections. Studies on the effect of nonylphenol on duckweed have been completed.

The Project Leader is on Career Development Leave at the University of Texas, Austin, to gain expertise in the development of insect larval tissues and organs, so that interference with these processes by applied control agents can be better understood and exploited.

PROJECTIONS: Work will continue on determining cellular and subcellular changes associated with the production of pheromones, cuticular waxes, and hormones, and on the cellular effect of pathogens, infections, and chemical pesticides. On the return of the Project Leader from her Development Leave, specific goals will be reviewed.

FP-22 IMMUNOCHEMISTRY

PROJECT STAFF:

Project Leader (Vacant), B. Mathieson

OBJECTIVES: *To develop and apply immunochemical and serological techniques to the identification and characterization of microbes and insect cell cultures.*

ACHIEVEMENTS: Serological studies at the Institute have been closely allied to other biological control projects for the past 25 years. A large number of *Bacillus thuringiensis (B.t.)* strains and isolates were identified and characterized, contributing to a fuller understanding of taxonomic relationships. This work identified a number of isolates with greater specific toxicity than that found in commercial preparations. The adaptation of a new assay technique led to quantitation of the toxic protein crystal control of various *B.t.* isolates. Serological techniques have also been

applied to characterization of viruses being studied at the Institute, and to identification of insect cell lines maintained here.

The Project Leader retired from the CFS in June, 1982. Accumulated results to that date were provided to cooperating scientists for inclusion into journal publications or other information activities. Technical support has been provided to the *B.t.* project for application of the ELISA (enzyme linked immunosorbent assay) techniques to quantitation of the *B.t.* crystal toxin and its components.

PROJECTIONS: With the retirement of the Project Leader, this project will be reoriented towards the serological and immunochemical characterization of insect pathogens as well as to the application of immunochemical techniques to the modification and virulence improvement of insect pathogens.

FP-23 BIOLOGICAL SYSTEMS ANALYSIS

PROJECT STAFF:

R.A. Fleming (Project Leader)

OBJECTIVES: *To develop original research in systems analysis contributing to the solution of forest pest and forest management problems, and to provide consultative advice to other researchers interested in using modelling and simulation in work related to pest management.*

ACHIEVEMENTS: This project was initiated in 1980. Between 1980 and mid-1982 a comprehensive review of the literature on modelling in forest ecosystems, and in particular the spruce budworm, was completed. Two cooperative projects with FPMI investigators were initiated. Problem definition, system-environment dichotomy, and variables that affect the system were identified.

The current Project Leader undertook his duties in June 1983. Substantial initiatives have been taken in three directions: fungal development models, the analysis and use of spruce budworm population count - tree damage survey data, and participation in the Permethrin Drift Study. It is hoped that the completed fungal development model will

explain interactions between some entomopathogenic fungi, the spruce budworm host, and the abiotic environment. Technical procedures will be developed to analyze spruce budworm survey data and to extract information relevant to forest pest management, which is not available from other sources. The role of this project in the Permethrin Drift Study is to provide a systems analysis perspective on the overall experimental design, and to synthesize the results produced by the separate parts of the study to achieve the overall study objectives.

PROJECTIONS: Established original research will continue and other possible research directions will be investigated.

Physiological and Genetic Mechanisms

A forest insect pest grows and develops through a complex and interrelated series of steps including larval and pupal stages, mating, and reproduction. As knowledge of the physiological and genetic mechanisms associated with such development become better understood, so do the opportunities to identify critical stages that can be manipulated to control economically important insect pests. The Institute program in this area includes research into the physiological mechanisms associated with normal growth and development, the physiological and behavioral aspects of insect mating and reproductive behavior, and the dynamics of insect population genetics. The possibility of manipulating these mechanisms, through chemical or other means, to the detriment of insect survival within a generation, and from one generation to the next arises from this research.

The research into these areas leads directly to the screening of candidate insect growth regulators and pheromones that have potential for use and the development of methods for their use. Genetic research not only identifies the stages of reproduction susceptible to manipulation, but also contributes significantly to the understanding of population dynamics and how it is affected by the application of control agents, whether they are biological or chemical.

FP-30 PHEROMONES

PROJECT STAFF:

G.G. Grant (Project Leader), D. Frech, L. MacDonald

OBJECTIVES: *To provide the prerequisite basic knowledge on the chemical identification, detection, and behavioral function of insect pheromones to advance their use in the control and monitoring of forest insect pests.*

ACHIEVEMENTS: Since 1968, the sex pheromones of several important forest insects including the spruce budworm, western spruce budworm, *Choristoneura orae,* forest tent caterpillar, and maple leafroller have been identified through cooperative studies. The spruce budworm pheromone is now commercially available. Attractants for other important species, such as the oak leaf shredder, have been developed as population monitoring tools. A sensitive bioluminescence technique for measuring small quantities of pheromone, developed in a cooperative CANUSA study, has been used to measure pheromone release rates from insects, trap lures and controlled release formulations. Mating and courtship studies, conducted on several moth species, have revealed the complexity of the interactions that occur between male and female moths and have emphasized the role of male and female sex pheromones in mating behavior. Several male sex pheromones have been identified.

During 1983-84, monitoring lures were refined for a number of tortricid forest pests including shoot moths *(Rhyacionia* and *Eucosma),* the oak leaf shredder, and the spruce seedworm. Work continued on a lure for *Zeiraphera canadensis.* In 1983, the Project Leader returned from Career Development Leave at the University of Southampton.

PROJECTIONS: During 1984-85, the development of monitoring lures for several of the above species should be completed; others from the spruce seedworm and spruce coneworm will still be under development. Work will be started on the use of the white pine weevil pheromone for detection. Courtship and mating behavior of the spruce budworm and whitemarked tussock moth will be undertaken to determine how various stimuli control these essential behaviors.

FP-31 INSECT GROWTH REGULATORS

PROJECT STAFF:
A. Retnakaran (Project Leader), L.F. Smith, W. Tomkins

OBJECTIVES: *To evaluate and develop the use of insect growth regulators for the management of Canadian forest pest insect species.*

ACHIEVEMENTS: This project has been investigating such alternative means of forest insect control as chemosterilants, radiation, and hormone analogs since 1968. Some of the successes have been control of the spruce budworm by the moult inhibitor CGA-112913, control of the forest tent caterpillar and oak leaf shredder by Dimilin, and control of the hemlock looper by the hormone analog ZR-515. Once the toxicology and environmental impact studies are completed to the satisfaction of the registration authorities, some of these methods will probably become operational.

During 1983-84, several new Insect Growth Regulators (IGR) and formulations were tested in the laboratory and in the greenhouse. (ME-13401) and an EC formulation of CGA-112913 proved to be exceptionally active on the spruce budworm. The latter compound was also found to be nonmutagenic in a bacterial mutagenicity (Ames) test using 6 strains of histidine auxotrophs of *Salmonella typhemurium*. It was also demonstrated that nuclear polyhedrosis virus (NPV) propagation in spruce budworm larvae can be increased if the larvae are treated with a juvenile hormone analog several days before they are infected with the virus. Aerial application of Dimilin at the rate of 70g in 4.7 L/ha effectively controlled the oak leaf shredder. Work on the biology of the white pine weevil was continued at Iron Bridge.

The Project Leader was away on Career Development Leave at the Commonwealth Scientific and Industrial Research Organization (CSIRO) Laboratory, Canberra, Australia from February 1983 to February 1984.

PROJECTIONS: The EC formulations of CGA-112913 will be field-tested against the spruce budworm, if a spray permit is obtained. The delayed effects of this compound on adult fecundity will also be studied. Based on the chitin synthesis investigations carried out in Australia, chitin synthesis in the spruce budworm will be examined to explain

the mode of action of benzoyl ureas. The control potential of Dimilin on Douglas-fir tussock moth will be studied in the laboratory and in the greenhouse.

FP-32 GENETIC APPROACHES

PROJECT STAFF:

In abeyance

OBJECTIVES: *To analyze the genetic components of insect reproduction and to investigate methods for manipulating pest abundance by genetic means.*

ACHIEVEMENTS: Since the project was initiated in 1972, chromosome numbers and sex-determining mechanisms have been determined for more than 100 species of Lepidoptera. These mechanisms have provided a clearer understanding of the genetic complement of this group of insects. Genetic studies, carried out in collaboration with staff at GLFRC, concentrated on the *Choristoneura* group and included analyses of chromosome relationships in seven species and their hybrids. The use of sterility to reduce population levels has been intensively investigated, with basic studies being carried out on mechanisms for inducing sterility, effects on treated insects, and reduction in population fertility resulting from introduction of sterile adults. The dispersal of released adult males was determined using pheromone trapping techniques. The effects of various sterilizing treatments on the ability of males to respond to pheromone attractants was also studied. Results to date indicate that the potential of this method lies with low-level isolated populations rather than large-scale epidemics.

This project was placed in abeyance in 1980 after the move of the project leader into a management position.

PROJECTIONS: Reactivation of the genetics project at the Institute will depend on availability of Person Year resources. The direction of the research is dependent on the type of genetics input required by other Institute projects in biological control.

Pesticide Toxicology and Efficacy

A wide variety of forest insect pests inflict severe damage on Canadian forests each year. The best estimates currently available suggest that the average loss in wood volume caused by the activities of our major forest insect pests approaches or exceeds some 63 million m^3 per annum. In addition, competition from undesirable tree species, grasses, and weeds often impedes the establishment, survival, and growth of desired crop species by as much as 50%. Losses of this dimension cannot be tolerated if Canada is to meet wood production goals accepted by the Canadian Council of Resource and Environment Ministers for the year 2000, or if we are to maintain Canada's share of the foreign market in wood and wood products, which is so vital to our national economy. Such losses can be prevented or at least reduced substantially by the judicious use of chemical pesticides. Most chemical insecticides and herbicides however, are developed by the pesticide industry first for the agricultural use market, which is very large and stable compared to the forestry use market. Before such materials can be registered and used for forestry purposes, their efficacy against forest insect pests and unwanted vegetation must be determined and dosage rates that will balance efficacy and acceptable environmental impact must be established.

To help ensure that forest managers have a range of effective insecticide and herbicide alternatives available for their use, the Institute maintains a continuing program that screens new products and modifies formulations of existing ones, to determine toxicity against a range of target pests. Those pesticides that appear to have potential for forestry use are tested in a series of field efficacy trials to establish actual use potential, required dosage rates, and use patterns after full consideration has been given to the biology of target pests and host species. The data generated by this program become essential components of the data package that is eventually submitted in support of registration of these pesticides for forestry use under the Pest Control Products Act. They also form the basis of control recommendations to forest managers.

FP-50 INSECTICIDE TOXICOLOGY

PROJECT STAFF:

B.V. Helson (Project Leader), D. Comba, J. McFarlane

OBJECTIVES: *To determine the toxicological properties of insecticides and their formulations, and other chemicals, on forest insect pests and selected nontarget organisms and for those that show potential for use, to provide possible dosage levels and use patterns for further field testing.*

ACHIEVEMENTS: Since the inception of this project, approximately 150 insecticides have been tested against some 25 major pests. Chemical insecticides such as fenitrothion, aminocarb, and acephate, which are now registered for large-scale forest insect control, were originally identified through this program. Within the past few years the study has provided information on pyrethroid insecticides, solvents, and carriers used in spray formulations. Permethrin, chlorpyrifos-methyl, Bolstar, solvent 585, and a Matacil flowable formulation have been recommended for field evaluation.

During 1983-84, several insecticides and formulations were tested against spruce budworm larvae to determine their direct contact toxicity, their residual toxicity, and their toxicity as foliar deposits. Sumithion Flowable and Zectran were recommended for field efficacy tests. The contact toxicities of aqueous and oil-based EC formulations of 4 pyrethroids were also determined to see if different formulations could improve the effectiveness and selectivity of these compounds to spruce budworm. Extensive tests were conducted with 1st- and 4th- instar spruce budmoth larvae to determine their susceptibility to several insecticides. A broad dosage range bioassay method was successfully used to determine the contact toxicity of 10 insecticides to mountain ash sawfly larvae. The relative toxicity of fenitrothion and aminocarb to andrenid, bumble, and honey bees was determined by topical application in a joint study with the Environmental Impact project. Two bioassay methods, which used mosquito larvae as an indicator species, were developed and used to assess the potential impact of permethrin drift on aquatic insects.

PROJECTIONS: Toxicological studies will be continued with new insecticides - particularly Zectran, Larvin, and AC217-300 - that may have potential for spruce budworm control. Investigations will also be carried out to determine the effects of host foliage, droplet size, and water vs oil carriers on toxicology of insecticides to spruce budworm. Cooperative studies will be continued to identify potential insecticides for the control of spruce budmoths, to determine the relative toxicity of forestry insecticides to beneficial nontarget insects, and to determine dimensions of buffer zones required to protect aquatic habitats from insecticide drift.

FP-51 INSECTICIDE FIELD EFFICACY

PROJECT STAFF:

B.L. Cadogan (Project Leader), P. Ebling, C. Nystrom, L. Pollock, B. Zylstra

OBJECTIVES: *To develop suitable methodology and data to assess the efficacy of new insecticides, formulations, and pest control strategies as required for the management of forest insect pests.*

ACHIEVEMENTS: Since its inception in the mid-1950s, this project has been primarily concerned with field efficacy testing of insecticides with potential for forestry use. Data arising from this project have been used to assess the efficacy of virtually all insecticides currently registered for forestry use in Canada today. Improved methods of applying these materials in a manner that optimizes effectiveness while minimizing environmental impact have been developed. During recent years the project has investigated the efficacy of chlorpyrifos-methyl, permethrin, carbaryl, and aminocarb flowable formulations and has provided virtually all of the efficacy data that contributed to the registration of permethrin and aminocarb flowable for forestry use in Canada.

During 1983-84, two strategies for the application of nuclear polyhedrosis viruses to control spruce budworm were evaluated in cooperation with the Viral Pathogens project. A study was conducted to characterize a new Sumithion

flowable insecticide before it was tested for field efficacy. A cooperative study, with the Pest Control Section of the Ontario Ministry of Natural Resources (OMNR) was carried out to investigate and evaluate three types of spray dispersal equipment. The second phase of calibrating the Institute's aircraft was completed. The project participated in a cooperative trial with the Spray Cloud Behavior and Herbicide Development and Use projects to investigate the spray outputs of a new Through Valve Boom (TVB) spray system.

PROJECTIONS: Field studies will focus on the evaluation of a new mexacarbate formulation (Zectran DB) and the new Sumithion flowable formulation which was characterized in 1983-84. The project will also be involved in a cooperative study with the Environmental Impact Project to study the effects of Zectran on songbirds.

FP-52 PLANTATION PEST MANAGEMENT

PROJECT STAFF:

J. Turgeon (Project Leader), P. deGroot (Study Leader), N. Charlebois, A. Obarymskyj

OBJECTIVES: *To study the ecology, biology, and behavior of insect pests of coniferous plantations grown for seed and timber production, and to evaluate their impact on the crop, and to develop protection strategies that provide maximum insect control with minimal environmental impact.*

ACHIEVEMENTS: In 1983-84, after a biennial project review, the Special Applications project was renamed Plantation Pest Management (FP-52) with two studies: Insect Ecology and Biology (FP-52-1) and Protection Strategies and Techniques (FP-52-2).

FP-52-1 completed some of the biological studies on *Z. canadensis;* most of this work will be completed by the end of 1984-85. Study FP-52-2 initiated the proposed field testing of candidate control products for *Z. canadensis.* This work should also be completed by 1984-85. The Study Leader for FP-52-2 has also been involved with other Institute scientists in the development of buffer zone dimensions for permethrin.

PROJECTIONS: While completing their work on *Zeiraphera*, both studies are preparing an in-depth project analysis on cone and seed research in Canada, identifying the most urgent problems on a national basis. By 1985-86 the project will be in a position to initiate studies, similar to those presently underway, on the most important pests affecting cone and seed production in Canada and strategies for their control.

FP-54 HERBICIDES DEVELOPMENT AND USE

PROJECT STAFF:

P. Reynolds (Project Leader), R. Prasad (Study Leader), J. Feng (Study Leader), D. Travnick, J. Yoo

OBJECTIVES: *To develop data required for the registration of herbicides for forestry use in Canada and to develop new and improved use strategies for forestry herbicides that provide maximum crop tree growth response with minimal environmental impact.*

ACHIEVEMENTS: The FPMI herbicides project was initiated in 1981 in response to concerns that had been expressed by forest managers about the scarcity of vegetation management tools. A comprehensive protocol has been established for the evaluation of new herbicides under laboratory, greenhouse, and field conditions.

During 1983-84, two positions within the project were staffed: a herbicide residue chemist and a technician. A herbicide residue laboratory was established. This laboratory is the only one of its kind in the CFS. A gas chromatograph and a high performance liquid chromatograph were purchased and are now operational. A greenhouse has been renovated for herbicide research. Cooperative research with public and private agencies and herbicide users was initiated. FPMI herbicide staff participated in, or helped to support, various field trials of Garlon, Velpar, and Roundup in Ontario, British Columbia, and New Brunswick. PRUF (Program in Research by Universities in Forestry) contracts to study Garlon, Velpar and Roundup soil leaching and degradation were established at the Universities of Toronto and Guelph. Much travel was done in New Brunswick, Nova Scotia,

Prince Edward Island, Ontario, and British Columbia to identify field research sites for 1984-85. Research will be done on these sites to eliminate gaps in research and to expedite forestry registrations.

PROJECTIONS: Field and greenhouse studies will be conducted to generate necessary data on efficacy, crop tolerance, residue, and environmental effects to register Velpar and Garlon for forestry use in Canada. Studies will be done on the influence of nozzle type on spray droplet deposition, efficacy, and crop tolerance. Potential field test sites in Newfoundland and Alberta will be visited. Significant herbicide efficacy and environmental impact studies with Roundup and Garlon will be undertaken with other FPMI, provincial and federal scientists in several areas in British Columbia in what are intended to be benchmark studies designed to address both federal and provincial regulatory and wildlife impact concerns.

Application Technology

The ultimate goal in the operational application of any pesticide by whatever application method is to assure that only the essential required amount of the pesticide is emitted, and that as much of the emitted material as possible reaches the intended target in a form that optimizes its effectiveness against the target pest. If this goal is achieved, drift beyond the target area is minimized and the effectiveness of the pesticide against its intended target is maximized.

A great number of factors affect achievement of this ultimate goal. For example, the physico-chemical characteristics of liquid sprays affect the production, size, and evaporation of the spray droplets. Dispersal system design, nozzle type, pressure, flow rate of the emission system, and speed of the vehicle carrying the emission system also influence the droplet pattern produced. Meteorological conditions during application affect the movement of the spray cloud, evaporation of the droplets, and penetration into and impaction on the forest canopy.

A thorough understanding of all of these factors and their interactions is essential if pesticides are to be applied in the most economical, efficacious, and environmentally acceptable manner. Therefore, research into all of these areas is an important aspect of the Institute's overall R & D program.

FP-60 DISPERSAL SYSTEMS

PROJECT STAFF:

Vacant

OBJECTIVES: *To test and assess new or modified spray emission systems on aircraft and ground spray equipment for improved pesticide applications.*

ACHIEVEMENTS: Research carried out during the 1960s on the basic principles of ultra-low volume application technology resulted in the introduction of incremental application technology of wide swath spraying using multi-engine aircraft, full span above-the-wing boom and open nozzle spray system, and electronic guidance systems for accurate swath alignment. A simple, compact, efficient, folding, flat-plate sampling unit was developed to ensure rapid retrieval of spray deposit data to provide reliable cumulative deposit results from both research and operational sprays. A compact emergence box was developed for the collection of 2nd- and early 3rd-instar budworm larvae from whole branch samples.

With the retirement of the project leader in December 1981 and the pressures of high-priority work programs (New Brunswick Action Plan), it was decided to delay staffing the project leader position, and to assign the technician to another project.

PROJECTIONS: Steps have been taken to initiate staffing of this project with the aim of having a new project leader on staff near the beginning of 1984-85. The project, when staffed, will concentrate on the modification and development of spray emission hardware that will produce pesticide spray clouds for forestry use with physical characteristics that will optimize efficient and effective deposit on target areas and reduce off-target drift.

FP-61 PESTICIDE FORMULATIONS

PROJECT STAFF:

A. Sundaram (Project Leader), J. Leung

OBJECTIVES: *To assess and/or modify the physical and chemical properties of pesticide formulations in order to improve upon stability, handling, dispersal and deposition characteristics required to maximize efficacy and minimize environmental impact.*

ACHIEVEMENTS: This project was initiated in 1980. During 1980-82, the project investigated the physical properties of various pesticide formulations, tank mixes, and component materials to determine their viscosity, density, surface tension, evaporation rate, and the influence of these factors on emission characteristics through a range of emission systems. A wind tunnel - spray chamber was constructed to study droplet production characteristics on a variety of targets in the laboratory. Actual deposition and distribution of droplets of various sizes on coniferous foliage were assessed in the field, using a new formulation that provided in-flight microencapsulation of droplets. This project was involved in the FPMI/CFS Action Plan to find replacement emulsifiers (to Atlox 3409F) for fenitrothion and aminocarb flowable insecticides. Tank mixes of emulsifiers and diluents that would provide the sprays with suitable physical characteristics were also identified.

During 1983-84, this project played a key role in coordinating the cooperative bird toxicity study done by the Canadian Wildlife Service (CWS) and FPMI. Spray exposure was carried out in the FPMI spray chamber. The use of a Laser Doppler Velocimeter was investigated in a cooperative study, under contract with Laurentian University, to explore the droplet spectra of various formulations in the spray chamber.

PROJECTIONS: The degree of adhesion of spray droplets of one *B.t.* formulation with and without stickers will be investigated. The optimum field diluent mixture for Matacil® 180 F will be investigated. Cooperative support will be provided to other projects requiring formulation expertise to carry out studies in application technology, spray drift assessment, efficacy, and environmental effects.

FP-62 SPRAY CLOUD BEHAVIOR

PROJECT STAFF:

N. Payne (Project Leader), J. Beveridge

OBJECTIVES: *To investigate and quantify the effects of physical parameters on spray cloud dispersal and deposition and to recommend application techniques and strategies which maximize efficacy and minimize off-target deposit, and cost.*

ACHIEVEMENTS: The spray cloud behavior project was formed in 1970 to carry out research to determine the meteorological conditions that will optimize spray deposition at the target. The project worked towards developing guidelines for spray operators to use in evaluation of meteorological conditions used for spray applications. The project existed without a project leader from 1978-1983. During this time, the technician carried out experiments to measure wind speed and temperature profiles inside the forest canopy, and participated in joint studies with other projects to provide meteorological instruments and measurements.

With the arrival of the new project leader in 1983, a detailed project analysis was carried out. A whirling arm facility for use in calibrating anemometers was designed and built. Sensitive propeller anemometers were acquired and installed on the meteorological mast. These will be used in making more accurate measurements inside the canopy. A computerized data acquisition system was purchased to improve and update the data processing capabilities of the project. Computer programs to acquire and process meteorological data were written and tested. Development of air samplers for measuring droplet concentrations was begun. Wind speed and temperature profiles were measured in and above a pine canopy. A brief comparison of the airborne pesticide concentration from two atomizers used in herbicide applications were made under typical operating conditions. A recently developed atomizer, the Through Valve Boom (TVB), was compared with a conventional hydraulic hollow cone nozzle.

PROJECTIONS: To provide information on off-target deposit to regulatory and provincial authorities, field trials will be carried out to measure airborne droplet flux at different

downwind distances from various herbicide and insecticide applications. Studies will be continued on the effect of meteorological conditions on spray cloud dispersal and deposition to provide spray operators with better guidelines. In particular, spray drift will be measured in boundary layers of different stability to determine which causes least drift.

Environmental & Amenity Forestry

Environmental Concerns

Before a pesticide can be used in Canada it must be registered under the Pest Control Products Act, which is administered by Agriculture Canada. Under the terms of this Act, a pesticide must be proved effective and its use must not have a significant, adverse impact on environmental quality or on human health. To have such materials registered for forestry use in Canada and to develop the most appropriate use patterns for them, it is essential that we have an adequate understanding of their impact on nontarget, naturally occurring species in the forest environment, and of their persistence, mobility, and ultimate fate in that environment. While such knowledge is essential for registration purposes, it is just as essential in adequately addressing public concerns relating to the use of these forest management tools.

A significant portion of the Institute's technical expertise and resources are directed toward determination of the effect of pesticides (chemical and biological) on nontarget avian, terrestrial, and aquatic organisms in the forest environment and to elucidation of the occurrence and fate of these materials, and their breakdown products in foliage, soil, litter, water, and bottom sediment after application.

FP-70 ENVIRONMENTAL IMPACT

PROJECT STAFF:

P.D. Kingsbury (Project Leader), S.B. Holmes, D.P. Kreutzweiser, B.B. McLeod, R. Millikin, K. Mortensen

OBJECTIVES: *To provide necessary ecological data to ensure that pest management strategies used in Canadian forests are environmentally acceptable.*

ACHIEVEMENTS: Over the past decade, this project has worked with other FPMI and CFS projects to evaluate the environmental effects of numerous chemical and biological insecticides. Work on products such as fenitrothion, aminocarb, acephate, *B.t.* permethrin, carbaryl, NPV, etc., has helped define the potential and conditions for using these products in the forest environment without causing undue harm to nontarget populations. A great deal of effort has gone into developing methodologies for monitoring the effects of forest pest control operations and transferring these techniques to regional and provincial agencies. Laboratory studies on pesticide-organism interactions have been conducted throughout the project's history. An intensive field research program into pesticide effects on forest ecosystems was initiated in 1980 in the Icewater Creek watershed near Sault Ste. Marie and has been a major focus for studies since.

Collection of baseline data in the Icewater Creek research area continued during 1983-84. Over 300 individual songbirds of thirteen selected species were color-banded for intensive studies on individual marked birds in their breeding territories. Brook trout density, growth, and movement data were collected by electroshock sampling over 1000 fish over the season. Wild pollinator visitations on 26 species of wildflowers, shrubs, and trees were censused over the season. Considerable sampling was carried out on larval and emerging aquatic and ground insects. Taxonomic evaluations to the species level, where possible, are in progress with the aquatic insect, pollinator, and ground beetle material collected from the Icewater Creek area over the past four years. As part of a cooperative study on permethrin drift from ground sprayer applications, field bioassays with a highly sensitive crustacean were carried out. A series of

topical application toxicity tests were conducted on andrenid, bumble and honey bees and ground beetles in a collaborative program with the Insecticide Toxicology project. The capability to determine bird brain cholinesterase was developed and a program evaluating seasonal changes in this parameter in white throated sparrows was carried out. Songbird populations were assessed in a large number of spruce budworm impacted and unaffected forest stands in six locations in Atlantic Canada to provide preliminary information on songbird responses to spruce budworm impacts.

PROJECTIONS: Baseline data collection at the Icewater Creek research area will be continued. Taxonomic evaluations of insect material will be completed. Toxicology testing of insecticides on wild pollinators will be continued and expanded to new species as opportunities arise. Environmental impact studies necessary for registration for forest pest control purposes will be conducted as required and will include assessment of any impact of herbicide applications of Roundup and Garlon in several watersheds of British Columbia in cooperation with other FPMI, federal and provincial scientists.

FP-71 CHEMICAL ACCOUNTABILITY

PROJECT STAFF:

K.M.S. Sundaram (Project Leader), C. Feng, J. Broks, R. Nott

OBJECTIVES: *To develop analytical methodology and determine the environmental distribution, degradation, dynamics, persistence, toxic potential and metabolic fate of forest pest control products in order to help in the evaluation of their benefits and potential risks to the ecosystem.*

ACHIEVEMENTS: The research of this project has provided sensitive analytical methods to identify and quantify various pest control chemicals and their metabolites used in forest spray programs and also their environmental persistence, mobility, cycling, toxicity and ultimate fate in different components of the forest ecosystem. Data generated in this project have been useful in evaluating the benefits and potential risks of spray operations and also in supporting the registration of fenitrothion, trichlorfon, acephate, carbaryl, and aminocarb insecticides.

During 1983-84, microcolumn cleanup and improved gas chromatographic techniques were developed for carbaryl and permethrin. Methodologies to quantify mexacarbate were evaluated and some preliminary studies were initiated to develop adsorption chromatographic techniques to remove coextractive impurities. Extensive field studies in New Brunswick forests demonstrated the presence of persistent fenitrothion residues at trace levels in conifer components of the forest environment. Aquatic model ecosystem studies were conducted to investigate the mobility and persistence of aminocarb and fenitrothion formulations. The data were related to field situations. The project participated in the collaborative research study to investigate the spray drift and deposition patterns of permethrin for establishing buffer zones around productive water bodies. Cooperative work was done with the Canadian Wildlife Service in a simulated aerial application study to investigate the behavioral pattern and enzyme inhibition effects of fenitrothion exposure to birds. The ongoing GC/MS and FICP Check Sample Program studies were evaluated and the data generated was compiled and interpreted.

PROJECTIONS: During 1984-85, the analytical methodologies initiated for permethrin and IGRs will be improved in sensitivity and selectivity. The study on penetration and metabolic fate of fenitrothion in different solvent mixtures to the 5th-instar spruce budworm larvae will be completed. Methodologies will be developed for the analysis of residues of mexacarbate and its metabolites present in various forestry substrates. The project will participate with others at the Institute in field trials to study: the environmental chemistry of mexacarbate to provide data to support registration of this material; the drift profile of permethrin to establish biologically effective buffer zones for use of ground application methods; and the exposure potential of mexacarbate to birds during experimental spray operations.

Complementary Research & Services

Complementary Services

Essential to the conduct of research at the Institute is a range of services which can produce the insect species, pathogens, and plant material required for laboratory research and field testing. Insects provided by the Insect Production section are used in a variety of laboratory experiment and testing programs, for production of insect viruses for field testing and operational use, and for distribution to a number of cooperators within and outside the CFS. The Pathogen Production section produces viruses for testing, and indeed, is presently the sole source for the two insect viruses registered for forestry use in Canada. In the Plant Production section are grown a variety of plant species required for insect food and for screening of biological and chemical insecticides, as well as representative desirable and undesirable species for use in screening of herbicides with potential for use in Canadian forestry.

FP-40-1 INSECT PRODUCTION

PROJECT STAFF:

D. Grisdale (Study Leader), K. Barratt, W. Bodley, C. Budau, L. Harwood, A. McMorran, P. Naphan

OBJECTIVES: *To develop and carry out insect rearing methods that will provide the numbers and varieties of insects required by Institute research projects.*

ACHIEVEMENTS: Since 1963, the insect rearing capability of this section has developed into the largest of its kind in Canada, supplying insects not only to FPMI but also to various CFS establishments, universities and other research centres in Canada and the U.S.

During 1983-84, seventeen species were again reared and over 5 million were produced. Large numbers of *O. leucostigma* and *C. occidentalis* were produced for virus multiplication. About 3 million *C. fumiferana* were produced, of which about 500,000 were used at the Institute for research. The remainder, composing about 300 shipments, were distributed to cooperating agencies.

PROJECTIONS: Production will continue at a high level, with types and numbers reared depending on demand.

FP-40-2 PATHOGEN PRODUCTION

PROJECT STAFF:

J. McPhee (Study Leader), H. Wigney

OBJECTIVES: *To produce sufficient insect pathogens to meet Institute research needs and operational requirements of clients.*

ACHIEVEMENTS: To date, pathogen production has been devoted exclusively to insect viruses. Material has been supplied for field trials conducted by the Viral Pathogens Project since 1970. Viruses produced in the laboratory include spruce budworm entomopoxvirus (EPV), nuclear polyhedrosis virus (NPV) granulosis virus (GV), Douglas-fir

tussock moth NPV, and forest tent caterpillar NPV. European pine sawfly NPV and redheaded pine sawfly NPV have been produced in the field by spraying heavily infested plantations and harvesting diseased larvae.

During 1983-84, production of spruce budworm NPV for experimental use and Douglas-fir tussock moth NPV (Virtuss) for operational use by British Columbia Ministry of Forests (BCMF) personnel continued. There is now sufficient Virtuss on hand to treat in excess of 2 000 ha when the next outbreak of this pest occurs in British Columbia. Redheaded pine sawfly NPV (Lecontvirus) was distributed to Ontario Ministry of Natural Resources (OMNR) clients in 7 districts. Forty plantations with a combined area of 211 ha were treated by OMNR. This virus was also supplied to the United States Department of Agriculture (USDA) Forest Service personnel to treat 400 ha in Florida. European pine sawfly NPV was supplied to Newfoundland Forest Research Centre (NeFRC) staff who treated about 5 ha in the city of St. John's.

Our viral products contain lyophilized virus-infected larvae ground to a fine powder and this material also contains a variety of bacteria. A quality control procedure has been established to enumerate these bacteria and to check for the presence of vertebrate pathogens. Formulation of viral material in an emulsifiable oil was found to be a convenient method of distribution to clients.

PROJECTIONS: Virus production will continue in order to meet Institute research needs and requests from clients. All efforts will be made to reduce production costs. Attempts will be made to mass produce the protozoan parasite, *Pleistophora schubergi*, as well as viruses.

FP-40-3 GREENHOUSE & ANIMAL SERVICES

PROJECT STAFF:

D. Buckley (Study Leader), N. Lautenslager

OBJECTIVES: *To operate greenhouse and animal rearing facilities that will provide, as required, material for Institute research use.*

ACHIEVEMENTS: Greenhouse facilities have been established that can provide a broad range of plant material for use in bioassays, insect production, single tree experiments and application technology development. Flushed potted trees are available nearly year round enabling screening activities and host-insect research to be carried out on a continuous basis. The animal facility maintains small mammals required for the Serology and Viral Biochemistry studies.

During 1983-84, capability for production of flushed potted trees was increased. As well, capability for production of seedlings and cuttings of various pest vegetation species was increased to support new initiatives in herbicide screening.

PROJECTIONS: Production will be maintained, with species produced to be determined by research requirements. Production of potted trees for bioassay tests, and vegetation for herbicide screening, will continue to increase.

Information & Technical Services

Information and Technical Services

No research can be considered complete until the results have been transferred effectively to potential users. The Forest Pest Management Institute (FPMI) is closely associated with other federal departments, other governments, private industry, and the Canadian public. It is therefore essential that results from the FPMI research program reach the publics for which they are intended. The Scientific Editing and Information Services unit is responsible for: developing and modifying the packaging and format of reports to meet changing demand; providing an editorial capability in both official languages; preparing and issuing regularly issued publications according to schedule; and, responding to requests for information.

The Information and Technical Services Unit at the Institute provides these and other services, contributing in a significant manner to the overall program at FPMI.

FP-93 SCIENTIFIC EDITING AND INFORMATION SERVICES

PROJECT STAFF:

K.B. Griffiths (Scientific Editor), S.A. Stitt (Graphic Illustrator)

OBJECTIVES: *To publish and disseminate scientific and technical information that arises from the Institute's program in the most appropriate form to facilitate the transfer of forest pest management science and technology to user groups.*

ACHIEVEMENTS: This project was initiated in 1980, and since then has provided liaison, technology transfer, editorial, and information services to the Institute. When the original project leader left the project in 1983, the project was reviewed and reorganized with the emphasis being put on the scientific editing and publications functions.

During 1983-84, the positions of Scientific Editor and Graphic Illustrator were staffed. Twenty-five journal papers, five information reports, and four miscellaneous reports were published through this project. The Program Review, a brochure for National Forest Week (Forest Pest Management...a helping hand), and four issues of the Newsletter were also published. During the year 1,916 journal reprints and 2,013 information reports were distributed. A rudimentary graphics centre was established. Institute displays were translated into French. Late in the 1983-84 year the project became involved in the initiation of an audio visual presentation, which will describe the Institute program and its role in the registration and use of forestry use pesticides. A new type of publication - the Technical Note - was designed and developed. The Institute's publications inventory was computerized.

PROJECTIONS: The position of bilingual Technical Editor will be staffed early in the 1984-85 year. The backlog of publications that need to be published in French will be cleared up. The format of the FPMI Newsletter will be enhanced. Involvement in the production of the FPMI audio visual presentation will continue, and a high level of scientific editing and information services will be maintained.

Administration & Common Support Services

Administrative and Common Support Services

Administrative Support Services (material management, records management, office services, fleet management, operation and maintenance of physical plant) and financial services are provided to both the Forest Pest Management Institute and the Great Lakes Forest Research Centre through one administrative unit carried on the Great Lakes Forest Research Centre allocation but responsible to the Directors of both establishments. Integration of these services has been total since 1978. Some economies in staff have resulted. These integrated services have functioned in a highly satisfactory manner since their inception, and are considered the most appropriate organizational option for sister establishments of the same service sharing the same physical facility.

Integrated joint library services are provided to both establishments in a similar fashion with permanent library staff carried on the Great Lakes Forest Research Centre allocation. This, too, has resulted in some economies in both staff and library space with the added advantage that library equipment and other facilities do not have to be duplicated.

As opportunities present themselves in the future, the desirability of further integration of common support services will be investigated thoroughly with the Great Lakes Forest Research Centre.

FP-97 ADMINISTRATION, FINANCIAL AND ENGINEERING SERVICES

PROJECT STAFF:

(GLFRC)

OBJECTIVES: *To provide effective and efficient administrative and financial services in support of FPMI's program; to provide adequate physical facilities within which the FPMI's R & D program may be carried out and to ensure that these are operated and maintained in the most efficient and effective manner.*

ACHIEVEMENTS: One administrative unit, carried on the Great Lakes Forest Research Centre (GLFRC) allocation, has served both GLFRC and FPMI since the latter was formed in 1977-78. Engineering Services were integrated in 1977 and the remainder of administrative and financial services followed in the beginning of fiscal 1978. This integrated system has served both establishments in a highly satisfactory manner to date.

During 1983-84 administrative, financial and engineering services continued to be provided in an efficient and effective manner. Word processing capability was significantly enhanced through the acquisition of additional equipment and through streamlining of operations of the typing services unit. A new Financial Officer position was created and staffed and improvements were made in financial accounting capability. The Institute's physical plant was maintained in an effective and energy-conscious manner. Phase I of a capital building project was completed providing additional greenhouse research space, storage and workshop facilities, chemical storage facility and an underground electrical power system on the entire site.

PROJECTIONS: During 1984-85, the Institute's vehicle fleet will be upgraded with 3 replacement vehicles and 1 additional special purpose vehicle. Internal financial services will be revamped and upgraded to provide managers with the level of financial information required for adequate control of financial resources. Phase II of the capital building project will be initiated - construction beginning in the first quarter on a 6000 m^2 laboratory addition and an addition to the administrative wing.

FP-94 LIBRARY SERVICES

PROJECT STAFF:

(GLFRC)

OBJECTIVES: *To provide essential library services to researchers and managers at the Forest Pest Management Institute in the most economical, effective and efficient manner.*

ACHIEVEMENTS: The joint library servicing both FPMI and GLFRC has served both establishments well since its inception in 1978. It provides upwards of 450 periodicals and abstracting journals for staff and has an accession list of more than 8000 reference texts covering the very broad range of subjects included in the R & D program of the two establishments it serves. With the addition of a computer terminal in 1982-83 the efficiency of literature searches was increased significantly.

In 1983-84, a new micro-fiche/film reader-printer was acquired facilitating the use of these microforms in the library; library staff acquired additional training in computer search on the Dialog System and a great deal of time was spent by the librarian in developing plans and specifications for a significant expansion to the library as part of the on-going major construction program at GLFRC/FPMI.

PROJECTIONS: In 1984-85 library staff will receive further training in the CAN/OLE data base system and considerable time will be devoted to planning for the move into the expanded library facilities to take place in late fiscal 1984-85.

Appendices

FOREST PEST MANAGEMENT INSTITUTE
EXPENDITURES 1983-84
($000s)

PROGRAM AREA	PERSON YEARS	SALARIES	OPERATIONS & MAINTENANCE	CAPITAL	TOTAL
Administration & Common Support					
Management	5	201.6	39.3	56.5	297.4
Administration & Finance	-	-	295.1	25.8	320.9
Physical Plant	-	-	249.0	6.6	255.6
Sci. Editing & Information	2	46.5	49.9	2.4	98.8
Library	-	-	50.9	-	50.9
Sub Total:	7	248.1	684.2	91.3	1 023.6
Improved Forest Management					
Microbial Control Agents	17	620.9	69.9	148.2	839.0
Biological Interactions	9	247.2	37.7	30.1	315.0
Physiological & Genetic Mechanisms	6	178.5	20.0	17.4	215.9
Pesticide Toxicology & Efficacy	16	532.9	122.9	130.4	786.2
Application Technology	5	166.5	35.5	87.7	289.7
Comp. Research Services	14	388.3	56.4	12.3	457.0
Sub Total:	67	2 134.3	342.4	426.1	2 902.8
Environmental & Amenity Forestry					
Environmental Impact	7	189.0	23.0	7.0	219.0
Pesticide Accountability	6	162.1	60.5	155.5	378.1
Sub Total:	13	351.1	83.5	162.5	597.1
TOTAL:	87	2 733.5	1 110.1	679.9	4 523.5
		SCIP EXPENDITURES	109.6		109.6
		PRUF CONTRACTS EXP.	68.1		68.1
			1 287.8		4 701.2

FOREST PEST MANAGEMENT INSTITUTE
RESEARCH & DEVELOPMENT CONTRACTS 1983-84

CONTRACTOR	TITLE	AMOUNT	SCIENTIFIC AUTHORITY
A. Chung Queen's University	Studies on the mode of liberation of nuclear polyhedrosis virus	$ 3,841*	J.C. Cunningham
D.E. Goldsack Laurentian University	Laser aerosol droplet measurements in FPMI spray chamber	5,000	A. Sundaram
P. Silk N.B. Research & Productivity Council	Identification of the sex pheromone of the spruce budmoth	2,000*	J. Turgeon
C.J. Wiesner N.B. Research & Productivity Council	Relationship of foliar deposit of *B.t.* to efficacy against spruce budworm	51,026*	T.J. Ennis
P. Silk N.B. Research & Productivity Council	Isolation, identification and synthesis of host-related chemical attractant to the native elmbark beetle	3,000*	G.G. Grant
G.M. Olah University of Laval	Investigations of the morphogenetic phenomena involved in conidial germination, germ tube penetration and host response	3,000*	D. Perry
S. Marshall University of Guelph	Taxonomic evaluation of collections of insect material from the Icewater Creek Research area	4,800	P.D. Kingsbury

FOREST PEST MANAGEMENT INSTITUTE
RESEARCH & DEVELOPMENT CONTRACTS 1983-84

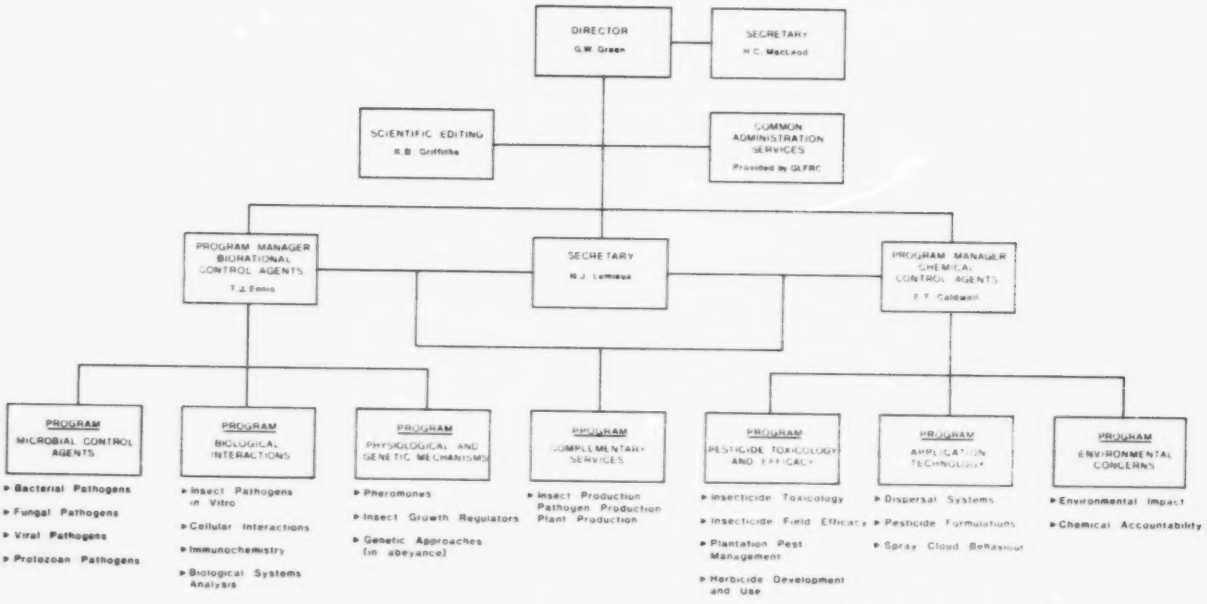
CONTRACTOR	TITLE	AMOUNT	SCIENTIFIC AUTHORITY
C.J. Wiesner N.B. Research & Productivity Council	Development of a tracer system to facilitate quantitation of *B.t.* on conifer foliage at aerial operation deposit levels	11,600*	T.J. Ennis
G.A. Surgeoner University of Guelph	Evaluation of insecticides used in spruce budworm control on non-target aquatic organisms utilizing a flow-through stream system	$ 6,500**	P.D. Kingsbury
C.C. Roder Queen's University	Production of monoclonal antibodies against components of baculoviruses and various components of baculoviruses and various fractions of the *B.t.* crystal toxin	11,283**	J.C. Cunningham
G.R. Stephenson & K.R. Solomon University of Guelph	Determination of the persistence, leachability and lateral movement of triclopyr in selected soil types	9,860**	P. Reynolds
D.N. Roy University of Toronto	Determination of the persistence, movement and degradation of hexazinone in selected boreal forest soils	19,815**	R. Prasad

FOREST PEST MANAGEMENT INSTITUTE
RESEARCH & DEVELOPMENT CONTRACTS 1983-84

CONTRACTOR	TITLE	AMOUNT	SCIENTIFIC AUTHORITY
D.N. Roy University of Toronto	Determination of the leachability, persistence, degradation and lateral movement of glyphosate in selected Canadian soils	20,637**	J. Feng
	TOTAL	$152,362	

*Contracts administered by FPMI but funding provided through the ToxFund or shared with other agencies.
**PRUF (Program of Research in University Forestry School) contracts.

FOREST PEST MANAGEMENT INSTITUTE - PROGRAM ORGANIZATION



FOREST PEST MANAGEMENT INSTITUTE
ORGANIZATION & STAFF LISTING
(As of 31 March, 1983)

Director	Dr. G.W. Green Secretary: H.C. MacLeod
Program Managers	Dr. T.J. Ennis Deputy Director Mr. E.T.N. Caldwell Secretary: N.J. Lemieux
Administrative Officer	R.M. Dean Great Lakes Forest Research Centre
Scientific Editing	K.B. Griffiths Editor S. Stitt Graphic Illustrator

RESEARCH & DEVELOPMENT PROJECTS

IMPROVED FOREST MANAGEMENT

MICROBIAL CONTROL AGENTS

Program Manager: Dr. T.J. Ennis

Project No.	Title	Scientific Staff	Technical Staff
FP-10	Bacterial Pathogens	Dr. P.G. Fast (Project Leader) Vacant (Study Leader)	R. Milne
FP-11	Fungal Pathogens	Dr. D. Tyrrell (Project Leader) Dr. D. Perry	K. Humphries M. Welton
FP-12	Protozoan Pathogens	Dr. G.G. Wilson (Project Leader)	E. Young

Program Manager: Dr. T.J. Ennis

Project No.	Title	Scientific Staff	Technical Staff
FP-13	Viral Pathogens	Dr. J.C. Cunningham (Project Leader) Dr. B.M. Arif Dr. W.J. Kaupp M. Legris	K. Brown R. Burke B. Cunningham

BIOLOGICAL INTERACTIONS

Program Manager: Dr. T.J. Ennis

FP-20	Insect Pathogens *in vitro*	Dr. S.S. Sohi (Project Leader)	G. Caputo B. Cook
FP-21	Cellular Interactions	Dr. J. Percy (Project Leader)	J.A. MacDonald D. Nicholson
FP-22	Immunochemistry	Vacant (Project Leader)	B. Mathieson
FP-23	Biological Systems Analysis	Dr. R.A. Fleming (Project Leader)	

PHYSIOLOGICAL & GENETIC MECHANISMS

Program Manager: Dr. T.J. Ennis

FP-30	Insect Pheromones	Dr. G.G. Grant (Project Leader)	D. Frech L. MacDonald
FP-31	Insect Growth Regulators	Dr. A. Retnakaran (Project Leader)	L.F. Smith W. Tomkins
FP-32	Genetic Mechanisms	Dr. T.J. Ennis (Project in temporary abeyance)	

PESTICIDE TOXICOLOGY AND EFFICACY

Program Manager: Mr. E.T.N. Caldwell

FP-50	Insecticide Toxicology	Dr. B.V. Helson (Project Leader)	D. Comba J. McFarlane

Program Manager: Mr. E.T.N. Caldwell

Project No.	Title	Scientific Staff	Technical Staff
FP-51	Insecticide Field Efficacy	Mr. B.L. Cadogan (Project Leader)	P. Ebling C. Nystrom L. Pollock B. Zylstra
FP-52	Plantation Pest Management	Dr. J. Turgeon (Project Leader) Mr. P. deGroot	N. Charlebois A. Obarymskyj
FP-54	Herbicide Development and Use	Dr. P. Reynolds (Project Leader) Dr. R. Prasad Mr. J. Feng	D. Travnick J. Yoo

APPLICATION TECHNOLOGY

Program Manager: Mr. E.T.N. Caldwell

FP-60	Dispersal Systems	Vacant (Project Leader)	
FP-61	Pesticide Formulations	Dr. A. Sundaram (Project Leader)	J. Leung
FP-62	Spray Cloud Behaviour	Dr. N. Payne (Project Leader)	J. Beveridge

ENVIRONMENTAL & AMENITY FORESTRY

ENVIRONMENTAL CONCERNS

Program Manager: Mr. E.T.N. Caldwell

FP-15	Environmental Impact	Mr. P.D. Kingsbury (Project Leader) Mr. S. Holmes	D.P. Kreutzweiser B.B. McLeod R. Millikin K. Mortensen
FP-16	Chemical Accountability	Dr. K.M.S. Sundaram (Project Leader) Mrs. C. Feng	J. Broks R. Nott

COMPLEMENTARY SERVICES

Program Manager: Mr. T.J. Ennis
Mr. E.T.N. Caldwell

Project No.	Title	Scientific Staff	Technical Staff
FP-40-1	Insect Production	Mr. D. Grisdale (Study Leader)	K. Barratt W. Bodley C. Budau L. Harwood A. McMorran P. Naphan
FP-40-2	Pathogen Production	Mr. J. McPhee (Study Leader)	H. Wigney
FP-40-3	Greenhouse Services	Mr. D. Buckley (Study Leader)	N. Lautenslager

The following list of publications includes only those papers published or issued during the 1983-84 fiscal year (April 1, 1983 - March 31, 1984). The material listed here includes only journal articles, book chapters, and Information Reports. Many other reports of an internal or special nature were written, but because they are not intended for general circulation, they are not listed here.

PUBLICATIONS

Arif, B.M.; Doerfler, W. 1983. Characterization of the DNA from *Choristoneura fumiferana* nuclear polyhedrosis virus. J. Bact. Hyg. A254: 147-148.

Cadogan, B.L. 1983. Biology and potential for increase of *Hellula phidileales* (Lepidoptera: Pyralidae). Environ. Entomol. 12(b): 1805-1807.

Cadogan, B.L.; Zylstra, B.F.; deGroot, P.; Nystrom, C. 1984. the efficacy of aerially applied Matacil to control spruce budworm, *Choristoneura fumiferana*, in Bathurst, New Brunswick. Can. For. Serv., For. Pest Manage. Inst. Inf. Rep. FPM-X-64, 33 pp.

Cunningham, J.C.; Kaupp, W.J.; McPhee, J.R. 1983. A comparison of the pathogenicity of two baculoviruses to spruce budworm and western spruce budworm. Can. For. Serv. Res. Notes 3(2):9-10.

Cunningham, J.C.; Kaupp, W.J.; McPhee, J.R.; Sheperd, R.F. 1983. Groundspray trials with two baculoviruses on western spruce budworm. Can. For. Serv. Res. Notes 3(2):10-11.

deGroot, P.; Cunningham, J.C. 1983. Aerial spray trials with a baculovirus to control redheaded pine sawfly in Ontario in 1979 and 1980. Can. For. Serv., For. Pest Manage. Inst. Inf. Rept. FPM-X-63, 12 pp.

Fast, P.G.; Dimond, J.B. 1984. Stadial susceptibility of spruce budworm *Choristoneura fumiferana* (Lepidoptera: Tortricidae) to *Bacillus thuringiensis*. Can. Entomol. 116: 131-137.

Fast, P.G.; Régnière, J. 1984. Effect of exposure time to *Bacillus thuringiensis* on the mortality and recovery of spruce budworm, *Choristoneura fumiferana*, Lepidoptera: Tortricidae. Can. Entomol. 116: 123-130.

Feng, C.; Sundaram, K.M.S. 1984. Multiresidue analysis of some insect growth regulators by reversed-phase high-performance liquid chromatography. J. Liquid Chromatogr. 7(1): 95-109.

Fleming, R.A.; Shoemaker, C.A.; Stedinger, J.R. 1983. Analysis of the regional dynamics of unsprayed spruce budworm (Lepidoptera: Tortricidae) populations. Environ. Entomol. 12: 707-713.

Fleming, R.A.; Person, C.O. 1983. Constant ranking, durability, and polygenic inheritance. Can. J. Plant Pathol. 5: 55-56.

Fleming, R.A.; Bruhn, J.A. 1983. The role of mathematical models in plant health management. Pages 368-378 in T. Kommedahl and P. Williams (eds.) Challenging Problems in Plant Health. American Phytopathological Society, St. Paul, Minnesota.

Gray, T.G.; Slessor, K.N.; Grant, G.G.; Sheperd, R.F.; Hosten, E.H.; Tracey, A.S. 1984. Identification and field testing of pheromone components of *Choristoneura orae* (Lepidoptera: Tortricidae). Can. Entomol. 116: 51-56.

Griffiths, K.B., comp. 1984. Forest Pest Management Institute Bibliography (1977-1982). Can. For. Serv., For. Pest Manage. Inst. Inf. Rept. FPM-X-60, 60 pp.

Hulme, M.A.; Ennis, T.J.; Lavallée, A. 1983. Current status of *Bacillus thuringiensis* for spruce budworm control. The Forestry Chronicle April, 1983: 58-61.

Kaupp, W.J. 1983. A staining technique for the inclusion bodies of a granulosis virus. Can. For. Serv., For. Pest Manage. Inst. Technical Note 1, 2 pp.

Kaupp, W.J. 1983. Estimation of nuclear polyhedrosis virus produced in field populations of the European pine sawfly, *Neodiprion sertifer* (Geoff.) (Hymenoptera: Diprionidae). Can. J. Zool. 61: 1857-1861.

Kaupp, W.J. 1983. Persistence of *Neodiprion sertifer* nuclear polyhedrosis virus on *Pinus contorta* foliage. Can. Entomol. 115: 869-873.

Kingsbury, P.D. 1984. Environmental impact assessment of insecticides used in Canadian forests. pp. 365-376 in Chemical and Biological Controls in Forestry. ACS Symposium Series No. 238. American Chemical Society, Washington, D.C.

Kingsbury, P.D., ed. 1983. Permethrin in New Brunswick salmon nursery streams. Can. For. Serv., For. Pest Mange. Inst. Inf. Rept. FPM-X-52, 192 pp.

Meating, J.H.; Lawrence, H.D.; Cunningham, J.C.; Howse, G.M. 1983. the gypsy moth situation in Ontario: general surveys, spray trials, and forecasts for 1983. Can. For. Serv., Great Lakes For Res. Centre Inf. Rept. O-X-352, 14 pp.

Meighen, E.A.; Szittner, R.B.; Grant, G.G. 1983. Determination of the release rate of aldehyde pheromones from insect lures by cold trapping and direct bioluminescence analysis. Anal. Biochem. 133: 179-185.

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Morris, O.N. 1983. Comparative efficacy of Thuricide 16B and Dipel 88 against the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae) in balsam fir stands. Can. Entomol. 115: 1001-1006.

Morris, O.N. 1983. Micro-organisms isolated from forest insects of British Columbia. J. Entomol. Soc. B.C. 80: 29-36.

Morris, O.N. 1983. Protection of *Bacillus thuringiensis* from inactivation by sunlight. Can. Entomol. 115: 1215-1227.

Morris, O.N.; Moore, A. 1983. Changes in spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae), biomass in stands treated with commercial *Bacillus thuringiensis* var. *kurstaki*. Can. Entomol. 115: 431-434.

Morris, O.N.; Moore, A. 1983. Relative potencies of 50 isolates of *Bacillus thuringiensis* for larvae of the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. Entomol. 115: 815-822.

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Percy, J.; Blomquist, G.J.; McDonald, J.A. 1983. The wax secreting glands of *Eriocampa ovata* L. (Hymenoptera: Tenthredinidae): ultrastructural observations and chemical composition of the wax. Can. J. Zool. 61(8): 1797-1804.

Percy, J.; Cunningham, J.C.; Burke, J.M.; Otvos, I.S. 1983. Viruses from the western false hemlock looper, *Nepytia freemani* (Lepidoptera: Geometridae). Can. Entomol. 115: 1239-1241.

Percy, J.; Fast, P.G. 1983. *Bacillus thuringiensis* crystal toxin: ultrastructural studies of its effect on silkworm midgut cells. J. Invert. Pathol. 41: 86-98.

Perry, D.F.; Latge, J.P. 1983. The effect of eight fungicides on germination of *Conidiobolus obscurus* resting spores. J. Invert. Pathol. 42: 83-86.

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Van Roermund, H.J.W.; Perry, D.F.; Tyrrell, D. 1984. The influence of temperature, light, nutrients and pH in the determination of the mode of conidial germination in *Zoophthora radicans*. Trans. Brit. Mycol. Soc. 82(1): 31-38.

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